



SCIENCE AND TECHNOLOGY FOR NAVAL WARFARE

2015 - 2020

August 2005



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**OFFICE OF THE ASSISTANT SECRETARY OF THE NAVY
(RESEARCH, DEVELOPMENT AND ACQUISITION)**

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COVER: China's first "Aegis" destroyer of the Lanzhou class (Type 052C). Note the electronically scanning radar antennas mounted below the bridge.

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**Naval Research Advisory
Committee Report**



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Foreword

Life in 2015 will be revolutionized by the growing effect of multidisciplinary technology across all dimensions of life: social, economic, political, and personal. ... The revolution of information availability and utility will continue to profoundly affect the world in all these dimensions. Smart materials, agile manufacturing, and nanotechnology will change the way we produce devices while expanding their capabilities. These technologies may also be joined by “wild cards” in 2015 if barriers to their development are resolved in time.

Philip S. Antón, Richard Silbergliitt,
and James Schneider
The Global Technology Revolution
Prepared by the RAND Corporation
National Defense Research Institute
for the National Intelligence Council,
2001

Study Sponsor: The sponsor of this study was the Deputy Chief of Naval Operations for Warfare Requirements and Programs (N6/N7).

Duration: The duration of the study was five months, during which the Panel held seven formal meetings. Thus, the Panel’s efforts were limited in time and scope. Accordingly, the Panel sought to primarily develop a systematic methodology for developing future S&T investment requirements.

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Executive Summary

The United States Navy and Marine Corps, tasked with providing forward maritime presence and the capability to respond rapidly to contingencies and crises worldwide, now confront complex new challenges in carrying out those missions. Continuing evolution in the geopolitical alignments in the Middle East, Southwest Asia, and the Pacific Rim; and the long-term global war on terror are accompanied by the proliferation of advanced weapon systems available to potentially hostile states and non-state terrorist organizations.

At home the sea services face severe budget constraints, debate over the scope of defense “transformation,” and such complex problems as the erosion of the U.S. technology base and the decline in the size of the U.S. science and technology workforce.

As the Navy and Marine Corps look toward the global scenarios of 2015 through 2020, they face a rapidly and dramatically changing threat, hence there is a pressing need to develop and field new weapons, sensors, command and control, and information management systems that incorporate advanced technology. These technologies are largely based on breakthroughs by commercial technology enterprises. The move to Commercial-Off-The-Shelf (COTS) technology brings new challenges in logistics support, training, reliability, maintainability, and possible vulnerabilities. Also, COTS hardware and software can be readily available to potential enemies.

The lack of an established long-term planning process for identifying and exploiting new S&T has limited the effectiveness of the Navy’s efforts to incorporate new technologies in the systems that will be needed in the 2015-2020 timeframe.

To meet the coming challenges and address the current shortcomings, the NRAC study team urges the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN (RDA)) to develop a long-term S&T planning process to identify gaps and to support the development of new Navy and Marine Corps capabilities. The Panel recommends the establishment of a long-term S&T workforce plan to reverse the “brain drain” faced by the Navy research establishment. It recommends that the ASN(RDA) and Navy acquisition officials find solutions to the growing costs of new systems and platforms through a variety of concepts that should be applied to future ship design on an integrated basis. Finally, the Panel recommends that the Navy establish a task force to identify the value and vulnerabilities of COTS and solve the problems of inserting new commercially developed technology in mission-critical Navy systems.

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Conclusion

The **bottom** line is that:

While the Navy has a productive S&T program today ...

The rapidly changing threat and the rate of world technological development demands change in the Navy-Marine Corps investment strategy for S&T over the next 15 years to ensure that the naval services can continue to effectively carry out their missions.

Failure to change the investment strategy for Navy-Marine Corps S&T will make technological surprise on the battlefield **likely** ... and success in executing naval missions will be **problematic**.

The world has undergone major changes since the end of the Cold War some 15 years ago. The rate of change can be seen in many areas, such as non-state terrorism, information and communication technologies, and medical science among others.

From a military perspective the rate of change has been dramatic. Despite major reductions in force levels, U.S. naval forces have undergone significant advances during the past 15 years. At the same time, foreign military developments have been most impressive and have included: electronically scanned array radars, air-independent submarine propulsion, advanced cruise missiles, unmanned aerial vehicles, sea mines, and torpedoes. Under development in various nations are also anti-ship ballistic missiles and other advanced weapons, sensors, and platforms.

At the same time, the role of U.S. naval forces in the next 15 years can be expected to grow as U.S. troops are withdrawn from Afghanistan and Iraq, the continued loss of overseas bases, and a resultant American reluctance to commit ground forces in response to crises and local conflicts. In the context of continuing overseas requirements and changing threats, U.S. naval forces must be more capable and more flexible to ensure their continued effectiveness.

Thus, adequate S&T investments must be made *now* to provide the means for that effectiveness. This NRAC study has developed a methodology to identify specific areas for S&T investment and makes specific recommendations.

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Terms of Reference

Identify the science and technology in which the U.S. naval forces should consider investing to counter predicted threats and to enhance the effectiveness of U.S. naval forces in the period 2015 to 2020 while undertaking Littoral Operations.

This study initially sought to identify the threat implications for three specific areas of the world; however, the issues appear to be universal because of the proliferation of weapons and systems that could threaten U.S. naval forces.

Although the geographic features of the three areas differ, the military implications for all areas appear to be similar.

The initial Terms of Reference tasked the Panel to identify science and technology in which the U.S. Navy should invest to counter anticipated threats to naval operations in the littorals of three specific areas (Middle East, Southwest Asia, and the Pacific Rim) in the period 2015-2020. In the course of the Panel's considerations, however, it became apparent that the technological issues identified were relevant across much of the spectrum of naval warfare and in essentially all littoral areas where U.S. naval presence or operations may be challenged.

In examining scientific and technological issues that could impact the Navy in the 2015-2020 timeframe, the Panel deliberately avoided any attempt to define scenarios, predict potential enemies, or identify specific areas where naval forces might be employed in the future. The Panel found that the importance of the issue transcended such considerations. History is replete with examples of the foolishness of attempting to make specific predictions of the future, especially in periods of rapid technological and geo-political changes, as are now being experienced. Still, sufficient trends are apparent today to allow an assessment of S&T issues, which are virtually certain to impact the Navy of 2015-2020.

A complete copy of the Terms of Reference can be found at Appendix A.

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Panel Membership

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The Panel membership was composed of members with strong backgrounds in (1) Department of Defense and Navy policy, (2) Industry, (3) Naval Operations, (4) Program Management, and (5) Technical Disciplines. In addition, the Panel benefited greatly from reviews by the Chairman, of the Naval Research Advisory Committee and Vice Admiral William C. Bowes, USN (Ret.).

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Global S&T Trends

- Continued asymmetric opposition to U.S. interests
 - Non-state actors
 - Nation states
 - Military actions
 - Against U.S. critical infrastructure
 - Against U.S. civilian population
- Continued dilution of U.S. S&T base
 - Foreign students outnumber Americans in advanced engineering and science curricula
 - Technical education losing to business and arts
 - Government laboratory positions less attractive
 - Foreign investment in technical education accelerating
- Globalization eroding U.S. technical dominance
- Impending oil availability crisis
 - U.S. dependence on Middle East oil
 - Near-term Chinese demand for oil
 - Changing situation in Venezuela
- Increasing U.S. dependence on foreign technology
- Worldwide access to advanced technology through foreign and U.S. sales and espionage
- Technological surprise is **probable!**

It can be assumed with a high degree of confidence that opposition to U.S. interests will continue to arise from non-state actors and nation states. It is conceivable that these could erupt into full-scale hostilities and for that reason it is essential that the U.S. Navy retain the capability to defeat a sophisticated enemy in a high-seas engagement as well as the capabilities for lesser confrontations and crises.

The Panel views a major conflict scenario as far less likely than a continuation of asymmetric threats to U.S. interests, either by non-state actors (e.g., Al Qaeda) or by nation states sponsoring non-attributable attacks on U.S. interests, either abroad or at home. It is reasonable to anticipate that these attacks will range from the technologically sophisticated to such simple weapons as mines, suicide bombers, and explosive-laden motor boats. U.S. Navy ships and personnel operating in forward areas will be obvious and inviting targets, as will the critical support infrastructure both overseas and--possibly--in the U.S.

At the same time that the conventional and asymmetric threats to U.S. interests are becoming more technologically capable, the U.S. S&T dominance is eroding at an increasing rate. Much has been written about the declining enrollment of U.S. students in science and engineering curricula, and the increasing proportion of foreign graduate students at U.S. universities. While many of these foreign students

elect to remain in the United States after graduation, very few choose to work for government laboratories, and policies on export control and personal security clearances are driving still more technically talented immigrants out of the national security areas. Indeed, salary structures and other incentives make it difficult to attract personnel from the shrinking pool of U.S. citizen graduates into government service. The Panel views the potential impact of this phenomenon on the U.S. Navy laboratory and R&D communities as a serious matter, one that the Navy needs to take into account when making intermediate and long-term plans.

The historic technological dominance of the United States is also threatened by the increased technological sophistication not only of traditionally technologically competent nations, such as the members of the European Union; but also by rising technological powerhouses such as China and India. The process of globalization has accelerated this shifting of the technological “center of gravity.” This trend is virtually certain to continue and over time this situation will have a dual impact. On the one hand, the United States will witness other nations driving the state-of-art in technologies that had been considered the domain of the United States. On the other hand, the United States could find itself increasingly dependent on foreign technology to field weapons and sensor systems.

This inexorable shift of technological competence abroad, when paired with the shrinking U.S. defense laboratory and R&D establishment, makes technological surprise not only possible, but probable.*

Another global trend that is certain to have implications for the U.S. Navy is the increasing worldwide demand for oil, and the continuing instability of several oil-producing nations, the most recent example of which is Venezuela. That country currently provides 18% of the U.S. oil imports. The Venezuelan government, increasingly hostile to the United States, is providing petroleum to Cuba, replacing the late-Soviet Union in that role. In return, Cuba is providing military, intelligence, and medical expertise to Venezuela with several thousand Cubans currently “in-country.”** The appetites of China, the E.U., and India for oil are expanding at least as rapidly as that of the United States, but oil production has yet to demonstrate an ability to expand at the same pace.

* Recent discussions on this subject include Sharon Begley, “U.S. Science Research Is in Danger of Losing Place on Cutting Edge,” *The Wall Street Journal* (12 August 2005), p. B1; and Robert J. Samuelson, “It’s Not a Science Gap (Yet),” *The Washington Post* (10 August 2005), p. A17

** A recent example of this was the visit of Venezuela’s president, Hugo Chavez, to Cuba in mid-August 2005, in part to attend the first graduation of the Latin American School of Medicine, a joint initiative of the two countries begun in 1998. This was Chavez’s fourth visit to Cuba in the past nine months for discussions with Cuban leader Fidel Castro.



Military Implications of the World of 2020 for S&T

This study makes no attempt to define the future or to draw possible scenarios for what the world will look like in 2015-2020. However, certain trends are obvious:

- Nuclear, chemical, bio weapons continue to proliferate
- Terrorism continues
- Increasing violence and political influence by non-state actors
- Proliferation of primitive (but effective) as well as modern weapons/systems
 - Improvised explosive devices
 - Man-portable air-defense missiles
 - Sea mines
 - Surface-to-surface missiles
- Growing foreign economic power and changing politics
 - Rapidly changing demographics
 - Major emphasis on advanced S&T education
 - Advanced weapon development and sales
- Development of significant regional military powers
 - Blue water navies: China, India
 - Regional navies: Iran

While avoiding any attempt to define the future or specify scenarios, the Panel believes that it is prudent to project the continuing proliferation of nuclear, chemical, and biological weapons and the systems to deliver them. Protecting the U.S. and its allies from this threat has great potential impact on the missions of the U.S. Navy in the 2015-2020 timeframe.

At the same time, inexpensive weapons available to state and non-state actors will complicate the Navy's ability to operate in forward areas of its choosing. These area-denial weapons include the comparatively crude improvised explosive devices (IEDs), sea mines, man-portable air defense missiles, and anti-ship missiles of increasing sophistication.

The Panel envisions a continuation--and probable acceleration--of advanced weapons development and sales, to the point that almost any anti-ship or anti-aircraft weapon is available on the open market to any nation that wishes to purchase it. The inevitable follow-on thesis to this, of course, is the availability of these weapons to non-state actors.

It is also important to reflect on the potential impact of the changing demographics of several nations that have a history of supporting U.S. interests or at

least not openly opposing them. For example, by the year 2020, France is projected to have a population that is approximately 45% Muslim; there is a similar trend in Germany, with a total of seven European countries now having Muslim populations in excess of one million persons (France, Great Britain, Germany, Hungary, Italy, Serbia-Montenegro, Spain). If Turkey is admitted into the European Union, the Muslim population of the entire E.U. could approach this same level not long thereafter.*

The implications for U.S. – E.U. relationships are significant because their respective interests periodically diverge because of economic competition or regional perspectives. The possibility of E.U. naval forces and U.S. naval forces in confrontational situations introduces an entirely new, and previously “unthinkable,” complication into U.S. contingency planning.

Finally, China and India are expending considerable resources to develop “blue water” navies through major acquisitions as well as domestic development of advanced weapons, sensors, platforms, command-and-control systems, and operational concepts. Their goals in this naval expansion are to ensure sea control of the Western Pacific and Indian Oceans, respectively, including key maritime straits. Iran’s goal is to become the dominant regional navy of southwest Asia, again with the ability to control critical straits in the area. The implications of these developments with respect to U.S. and certain shipping routes for Middle East oil are obvious.

*See, for example, Peter Grier, “A Crescent Over Europe?” (*Air Force Magazine*, July 2005), pp. 64-67.



Navy-Marine Corps Missions in 2020

Many missions are similar to the Cold War era—BUT with significantly different emphasis

- ↑ Provide seaborne missile defense
- ↑ Provide seaborne support for operations against terrorism (including homeland defense)
- ↑ Protect U.S.-Allied maritime areas of interest (inc. SLOCs)
- ↑ Project military power (presence/rescue/peacekeeping/strike/assault)
- Threaten military forces of potential enemies (especially their WMD capabilities)
- ↓ Deter nuclear attacks (Trident SSBNs)

Before addressing S&T requirements for naval systems to operate successfully in the 2020 environment, the Panel made a list of expected U.S. Navy and Marine Corps missions in 2020. While many of the missions of the Navy and Marine Corps envisioned for the period 2020 appear to be little changed from the Cold War era, mission emphasis has changed.

The proliferation of Weapons of Mass Destruction (WMD) and their delivery systems will present the Navy with an increased sea-based missile defense mission. The Navy and Marine Corps also will increasingly be called upon to participate in operations against terrorism, many of which are evolving and not yet fully apparent. These operations will include homeland defense.

Protection of U.S. and allied maritime areas of interest will continue to be a high priority mission, especially in littoral areas, where acoustic conditions, heavy merchant and fishing traffic, and other factors could complicate naval operations. Similarly, protection of Sea Lines of Communications (SLOC) could again become a high priority mission if overseas oil supplies are threatened or if the seaborne logistics tail supporting U.S. military operations is placed at risk. While some may consider these SLOCs to be regional rather than oceanic, their distances from the U.S. will make them “long-range” operations from a U.S. Navy perspective.

The Navy-Marine Corps mission of projecting military power—in all of its various forms—is also expected to become more critical in the coming decade, in part because of the continuing withdrawal of U.S. forces from land bases in both Europe and Asia, and the increase in the number of areas of potential crises and conflicts.

This potential use of U.S. military power overseas will be across a broad spectrum of activities, including military presence, rescue of U.S. citizens, peacekeeping, strike, and assault.

The Panel does not view the mission of threatening the military forces of potential enemies as a changing or increasing mission. Rather, there will likely be a new emphasis on the previous four missions, with a residual and continuing effort to track, target, and be capable of striking enemy military forces, especially their WMD capabilities.

In the context of traditional strategic deterrence of nuclear attacks, the Panel envisions a reduction in emphasis. This will likely be manifested in a reduction in the number of Trident strategic missile submarines (SSBN) from the current force of 14 submarines, although the Navy's 30-year shipbuilding plan as presented to Congress shows a force of SSBNs for the entire term. This decline in emphasis should not be considered as a deterrent to an eventual follow-on submarine-launched strategic missile system.



Threats Impacting Navy-Marine Corps Missions

- Increased availability of long-range weapons against naval-maritime formations
 - Ballistic missiles with terminal guidance
 - High-speed, sea-skimming cruise missiles
 - EM Guns
- Proliferation of nuclear, chemical, biological weapons
- Proliferation of inexpensive delivery systems and weapons, including
 - Air (UAVs, mini-UAVs)
 - Surface (USVs)
 - Underwater (UUVs, mines, mini-submarines, SDVs)
 - Land mines, IEDs, and other low-tech systems
 - MANPADS, laser devices, and other high-tech systems
- Proliferation of advanced submarine technologies and concepts of operation
 - Propulsion
 - Sensors
 - Stealth
 - Weapons
- Proliferation of capabilities for sophisticated information warfare
- Increase in vulnerabilities of U.S. logistics
 - Pipeline
 - Overseas procurement of goods and services
- Near-continuous surveillance of U.S. land and sea forces by opposing military and commercial satellites, “cheap” UAVs, and other means
- “Network centricity” creates vulnerabilities for U.S. forces
 - Interruption/jamming
 - Effective EMCON impossible
 - Information overload
 - Over-dependence on reachback
- Loss of low-observable effectiveness
- Reliance on GPS makes it a major target

After reviewing potential U.S. Navy and Marine Corps missions, the Panel “played” the Global Trends and Military implications of the world of 2020 against those missions. These potential threats are obvious, although the following few points should be emphasized.

Increased availability of long-range weapons against naval-maritime formations: (1) China is believed to be developing anti-ship ballistic missiles with terminal guidance; (2) cruise missiles with very high Mach numbers are under development by several countries; and (3) Electro-Magnetic (EM) guns in development by several countries and, (4) as direct-fire as well as indirect-fire weapons, could threaten U.S. naval forces.

Proliferation of inexpensive delivery systems and weapons: Of particular interest to the Panel was the broad proliferation of inexpensive delivery systems and weapons. The Panel noted the use of an unmanned aerial vehicle (UAV) by the Hezbollah terrorist group for a reconnaissance flight over northern Israel in November 2004. The Israelis were able to detect but not intercept the aircraft. That was probably the first use of a UAV by a terrorist organization.

Proliferation of advanced submarine technologies: Advanced submarine technologies—for submarines, midget submarines, and swimmer-delivery vehicles are being widely proliferated. Special note should be taken of (1) reported negotiations for the transfer of an advanced Soviet Akula (Project 971M) to the Indian Navy,* and (2) an advanced propulsion system—that may be a form of nuclear propulsion, or Air-Independent Propulsion (AIP)—in Chinese submarines.

Similarly, advanced submarine weapons are readily available on the “open market,” including the Shkvall (“squall”) 200-knot torpedo, wake-homing torpedoes, large-diameter (650-mm) torpedoes, tube-launch cruise missiles, etc. A combination of advanced submarine systems and the increasing technical competence of Third World naval personnel will enable these platforms to threaten U.S. Navy operations in littoral waters.

Increase in vulnerabilities of U.S. logistics: Of particular concern are (1) the vulnerability of U.S. logistics ships and of the maritime pre-positioning ships that will be the core of sea basing, (2) the overseas procurement of goods and services, including the purchase of fuels and food that may be contaminated, and (3) the use of local security forces when U.S. ships visit foreign ports.

Loss of low-observable effectiveness: In the world of commercial photo satellites, high-speed communications, relatively cheap UAVs, and ubiquitous press coverage, it has grown difficult to hide the presence of Navy-Marine Corps forces in offshore areas. Similarly, conventional approaches to low-observable configurations for various platforms are being countered by sensor developments, some making use of commercially available components.

*India is the only nation to have operated a non-domestically constructed nuclear submarine, having previously sailed a Soviet-built Charlie class (Project 670) cruise missile submarine from 1988 to 1992.

“Network centricity” and the Global Positioning System (GPS) represent very critical nodes in U.S. naval operations that, because of reliance on them for effective combat operations, become a “magnet” for enemy efforts to interrupt and destroy those systems. For example, the current Department of Defense (DoD) assessment * of Chinese military power discusses potential attacks on U.S. networks:

China’s computer network operations include computer network attack, computer network defense, and computer network exploitation. The People’s Liberation Army (PLA) sees this as critical and emphasizes the need for “electromagnetic dominance” early in a conflict and as a force multiplier.

And:

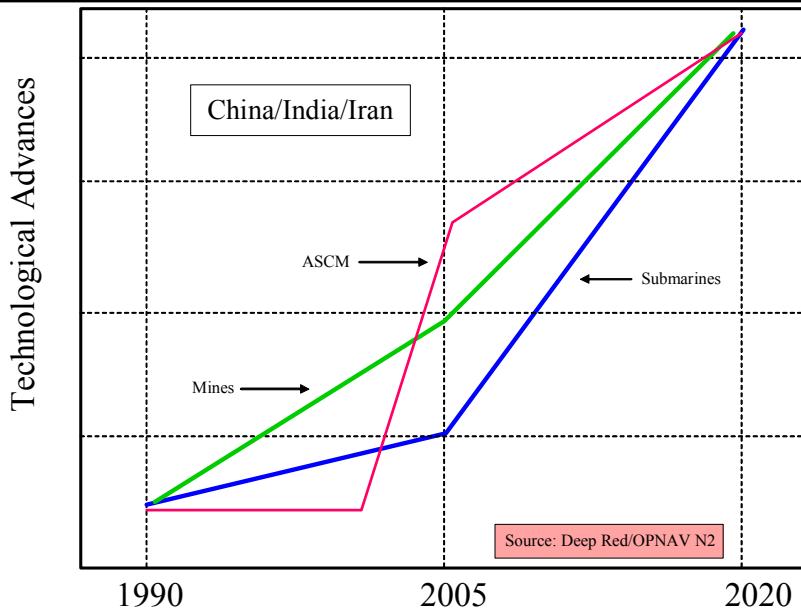
The PLA has increased the role of computer network operations in its military exercises. Although, initial training efforts focused on increasing the PLA’s proficiency in defense Measures; recent exercises have incorporated offensive operations, primarily as first strikes against enemy networks.

Beyond their potential vulnerabilities, the U.S. reliance on network- centric warfare make Emission Control (EMCON)—“turning everything off”—impossible for effective operations. By 2015, every air-launched weapon in the U.S. inventory will be dependent on GPS for primary guidance. Although alternative and combination guidance systems are available, at this time they are not being pursued.

* Department of Defense, “Annual Report to Congress: The Military Power of the People’s Republic of China 2005” (July 2005), p. 36. (PLA in this context includes Chinese naval forces.)

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Increasing Anti-Access Capabilities



The Panel also looked at several trends in Third World advances in weapons technologies and capabilities. This chart addresses three of those anti-access threats—Anti-Ship Cruise Missiles (ASCM), mines, and submarines. The vertical axis on this slide does not depict numbers of weapons and platforms. Rather, it is an attempt to illustrate the rate of increase in the level of technological sophistication and capability of Third World weapons designed to deny access to naval forces.

The recent advances in ASCM technologies reflect, in part, the recent transfer of Russian-developed cruise missiles and their technology to China and India; the advances in submarine technologies reflect the probable impact of Air-Independent Propulsion (AIP) and possibly nuclear propulsion technologies.

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Technology Traceability to Missions and Threats

		Threats Impacting Missions										Mission-Enabling Technologies									
Missions	Counter-Threat Technologies	Advanced Submarines	Continuous Surveillance by Potential Adversaries	GPS as Common Point of Vulnerability	Inexpensive Delivery Systems	Information Warfare Proliferation	Logistics Pipeline Vulnerability	Loss of Low Observable Effectiveness	LR Delivery Systems	Net-centricity Vulnerability	WMD Proliferation	Advanced AAW	Antenna Technology	Coordinated, Multimode ASW	Effective C2 in EMCON	Environmental Sciences	Lower-Cost Platforms	Offensive Mine Warfare	Pattern Recognition & Anomaly Detection	Robust Offensive Information Warfare	Upstream Information Fusion
		Provide Seaborne Missile Defense	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
		Provide Seaborne Support for GWOT		●		●															
		Protect Maritime Areas of Interest	●	●		●	●	●	●	●	●										
		Project Military Power	●	●	●	●	●	●	●	●	●										
		Threaten Adversary Military Forces	●	●	●	●	●	●	●	●	●										
		Deter Nuclear Attacks			●																
		Active Acoustic Systems	●			●															
		Discrimination & Clutter Rejection	●			●															
		False Target Generation & Deception		●																	
		Foreign S&T Awareness	●	●	●	●	●	●	●	●	●	●									
		Formal Methods for VVA					●														
		GPS Alternative			●																
		GPS Deep-Fade Technology			●																
		Information Assurance					●				●										
		Overseas Supply Chain Surety						●													
Overarching Issues																					
Formal mechanism for assessing U.S. vulnerabilities																					
Fundamental understanding of COTS																					
Long-term program to develop S&T workforce																					
Improved coordination of R&D programs																					
Requirements-linked, long-range planning process for S&T investment strategy																					
Long-range S&T review																					

Having looked at missions and threats, the Panel developed a systematic methodology for addressing technology requirements. The matrix shown above does not prioritize comparative level of threat or effectiveness of technology.

First, the Panel listed the six (previously discussed) **Missions** for the U.S. Navy and Marine Corps in the 2020 period.

The previously discussed **Threats Impacting Missions** were added, but in the context of specific missions.

Next, the Panel derived a set of **Counter-Threat Technologies** that are added to the matrix in alignment with the specific threats to naval missions.

The Panel then, derived a list of **Mission-Enabling Technologies** that are believed to enhance basic mission effectiveness; this list does not take into account the threats to missions.

Finally, the Panel identified six **Overarching Issues** that impact most of the Counter-Threat Technologies and the Mission-Enabling Technologies that were considered in this effort.

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Finding 1

Counter-Threat Technologies Investments

- Tactical/Operational
 - Active acoustic systems
 - Discrimination and clutter rejection
 - False target generation for deception
 - GPS deep-fade technology
 - GPS alternative
- Logistics
 - Security for overseas supply chain
- Capabilities/Systems Development
 - Foreign S&T awareness
 - Formal, automated methods for Verification, Validation, and Accreditation
 - Information assurance

The Panel identified nine areas of recommended S&T investment for Counter-Threat Technologies. These recommendations are presented in alphabetical order within each category.

Tactical/Operational

1. Active acoustic systems: The problems of detection of low-noise-level, non-nuclear submarines, especially in the littoral environment, demand new approaches to anti-submarine warfare (ASW). Several non-acoustic programs are now underway in the U.S.. In addition, the Panel recommends consideration of an acoustic illumination system to detect submarines, UUVs, and SDVs in restricted areas, such as straits and passages. Such a system should be remotely controlled, rapidly and covertly deployed, and transportable by submarine and possibly by aircraft.

2. Discrimination and clutter rejection: Advanced technologies to address low signal-to-noise ratios and integrating multiple sensor systems to enhance the effectiveness of weapon systems, autonomous vehicles, and sea mines.

3. False target generation for deception: Real and virtual false target generation systems to deny and deceive the enemy with regard to the location of U.S. fleet elements. This will be an increasingly difficult task because of the proliferation of advanced surveillance systems and platforms.

4. GPS deep-fade technology: The Panel is concerned about the potential vulnerability of GPS to jamming and interference in an era when U.S. military forces are becoming increasingly dependent on GPS capability. Increased emphasis must be placed on improving the Signal-to-Noise Ratio (SNR) when using GPS in restrictive

environments (such as buildings) and in poor weather conditions, and enhancing GPS effectiveness (including repeaters and graceful degradation).

5. GPS alternative: The Panel considers it prudent to provide alternative and complementary methods of missile targeting that at this time are planned with GPS-only guidance.

Logistics

6. Overseas supply chain security: The Navy's logistics ships and maritime prepositioning ships are considered highly vulnerable to a variety of threats. These ships are civilian manned and despite small Navy security detachments, remain vulnerable. Appropriate S&T investment could help to develop defenses against several types and levels of threats.

The vulnerability of the overseas supply chain must be of concern in an era when simple, easily delivered biological weapons are becoming more available to terrorists. As a minimum, the Panel recommends that studies be conducted to determine vulnerabilities, recommend inspection techniques, and assess alternative sources of supply, to include overseas procured fuel and food. In addition, U.S. naval logistics in some scenarios are vulnerable to infiltration by local, hired security forces during port visits.

Capabilities/Systems Development

7. Foreign S&T awareness: The Panel is concerned that as U.S. technological dominance decays, the nation is in danger of becoming less aware of activities and progress in foreign laboratories and R&D establishments. The Panel believes that the only way to maintain awareness of foreign R&D is through development of a structured "data mining" process that emphasizes statistical set analysis. Such an effort must be undertaken with support of the DoD. This is an area in which the Navy cannot depend exclusively (or even largely) on the intelligence community.

8. Formal, automated methods for verification, validation, and accreditation: The extensive use of Commercial Off-The-Shelf (COTS) technology in naval systems—both hardware and software—presents a number of potential vulnerabilities. Despite the wide use of COTS software in enterprise systems, such software is seldom fully documented and often installed after only limited testing. In many cases, the purchaser rarely knows the "internals" of the acquired COTS system. While Trojan Horses, trap doors, etc., are a concern, a greater concern should be the lack of system knowledge regarding how and when systems might fail and where potentially "fatal" weaknesses might lie.

The Panel believes that the Navy should require a formal, automated method to conduct full scale Verification, Validation, and Assurance (VV&A) of mission critical COTS software and systems, with a methodology developed to determine the criteria for future COTS acquisition.

9. Information assurance: As previously stated, the Panel believes that information assurance is becoming the single most critical capability needed by U.S. naval forces to effectively conduct operations in the network-centric environment. The dependence on broad-band communications, “reachback,” and instant, multi-node information exchange make U.S. forces an inviting information warfare (IW) target. A number of foreign open-source articles have been written pointing to the vulnerability of IW attacks on U.S. “information-dependent” forces. This vulnerability must be addressed as new architectures are created. New architectures must address bandwidth and alternative path challenges.

The Panel does not have a full understanding of the efforts currently underway in the IW arena. However, the Panel strongly recommends that this be a priority area for Navy investment and that a specific program be put in place to assess IW vulnerabilities of the FORCENet architecture in particular.

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Finding 2

Mission-Enabling Technologies Investments

- Tactical/Operational
 - Advanced AAW
 - Coordinated, multimode ASW
 - Effective C² in EMCON
 - Offensive mine warfare
 - Pattern recognition and anomaly detection
 - Robust offensive information warfare
 - Upstream information fusion
- Capabilities/Systems development
 - Antenna technology
 - Environmental sciences (specific areas)
 - Low-cost platforms technologies

The Panel identified ten areas of recommended S&T investment for Mission-Enabling Technologies. These recommendations are presented in alphabetical order within categories.

Tactical/Operational

1. Advanced AAW: The proliferation of UAVs that are capable of delivering biological and chemical agents, conventional warheads, and performing reconnaissance, must join the array of threats to be addressed by future AAW systems. When one includes the potential threats from anti-ship ballistic missiles and high-mach Anti-Ship Cruise Missiles (ASCM), it becomes obvious that a major S&T effort is required to develop the generation-after-next AAW system. The Panel believes that EM guns and advanced “conventional” guns offer promise for effective point-defense AAW weapons.

2. Coordinated multimode ASW: With the demise of the Soviet Union, ASW lost its traditional position as a high-priority Navy mission. While there has been renewed emphasis in this area, the Panel believes that the Navy’s ASW capabilities are not keeping pace with the emerging threat and considerably more emphasis needs to be placed on ASW. In particular, the Panel, after reviewing some advanced ASW programs, believes that the active acoustic system discussed above is a valid requirement, but so too must be advanced systems and concepts for the real-time integration of various ASW sensors and platforms.

3. Effective C² in EMCON: As previously discussed, the Panel is concerned that a network-centric Navy and Marine Corps will not have the ability to operate in EMCON. The Panel considers this capability critical in the era of readily available sensor systems. While there are some programs in this area, an increase in S&T

efforts is required to enable fleet operations in EMCON or an otherwise denied communications environment.

4. Offensive mine warfare: The U.S. Navy should consider employing mines in offensive operations, to create barriers to deny areas of interest/operations to hostile submarines, UUVs, and SDVs. The current U.S. mine capability is limited and rapidly dying. It is unlikely that the planned 2020 Mine will be developed on time, at cost, and with the capabilities originally expected. Accordingly, the Panel recommends the use of existing and in-development foreign-built mines that could be fitted with advanced sensors to meet the use described above. Similarly, a suitable Concept of Operations (CONOPS) must be developed.

5. Pattern recognition and anomaly detection: In an era of combat operations in “information overload” environments, it is increasingly important to provide the on-scene decision-maker with automated tools to sort the “wheat from the chaff.” Among these tools are advanced software programs to enable pattern recognition and anomaly detection. After an event, it is easy to accuse someone of “failure to connect the dots.” But when the dots themselves are obscured in a torrent of data, connecting them becomes an impossibility.

6. Robust offensive IW: The current IW capabilities must be expanded in the context of naval operations against non-state actors, i.e., terrorist and other non-regular groups employing Radio Shack-procured communications and intercept equipment. While the “bad guys” are increasingly listening to U.S. military communications, they also need to communicate.

7. Upstream information fusion: Closely related to the above (#4 and #5) is the requirement for upstream information fusion. Shipboard personnel are not capable of digesting and analyzing the vast data flows that are available to them. This will only be exacerbated with the deployment of the littoral combat ship and the large-scale personnel reductions being planned for other new ships such as the DD(X) and CVN-78. Dedicated shore facilities similar to the Navy-operated Ocean Surveillance Information System (OSIS) of the Cold War era are required to provide tailored support to forces afloat at a level of detail and responsiveness that the current Joint Intelligence Centers (JIC) and Washington-level commands have proven unable to provide.

Capabilities/Systems Development

8. Antenna technology: The Navy and Marine Corps emphasis on network centric warfare demands increased communications and additional bandwidth. This is limited to a large degree by antenna characteristics. These are problems for most naval ships, but especially for smaller surface ships, such as the littoral combat ship, and for submarines. Currently fielded antennas have large radar signatures, require significant space, and have topside weight implications that make them difficult to employ on any but the largest of ships.

In 2004 the Naval Research Laboratory (NRL) successfully tested a shared-aperture antenna, and has development efforts underway to explore other promising areas of non-conventional antenna design. Such efforts must be accelerated, with appropriate S&T being allocated for multi-mode, multi-function antennas with broad bandwidth capabilities that do not compromise low-observable characteristics. Further, efforts should be examined for employing non-communication satellites as relay platforms and, when “visible,” employing the moon as a gigantic communications reflector.

9. Environmental sciences: The Panel believes that the Navy should allocate additional resources to environmental sciences, particularly in the area of understanding the ocean. Two particular areas require additional S&T support: (1) the understanding of the “noise” in the SNR of the littoral environment and (2) the impact of high-powered acoustic emissions on marine life. The latter is needed to help ensure that future naval operations employing active sonar are not degraded because of environmental limitations on naval exercises and systems development.

10. Lower-cost platforms: As recently publicized, the DD(X), CVN 78, and VIRGINIA (SSN 774) programs are experiencing significant increases in cost over original or early estimates. The Navy may be “pricing itself out of the ship market,” according to some press reports. The Panel recommends that increased emphasis be placed on ensuring that future ship designs make maximum use of current and near-term future technologies and procedures that can make ships more affordable.*

While the Panel recognizes the potential for making ships more “affordable” by limiting combat capabilities, it believes that the employment of innovative technologies and approaches can enhance combat capabilities at reduced costs.

* See, for example, Naval Research Advisory Committee report “Science and Technology for Modular Systems” (2004).

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Finding 3

Overarching Issues Requirements

- Formal mechanism for assessing U.S. vulnerabilities
- Fundamental understanding of COTS
 - Business models
 - Technology drivers
 - Standards
 - Internal structure, functionality, vulnerabilities
- Long-term program to develop S&T workforce
- Improved coordination of R&D programs
- Requirements-linked, long-range planning process for S&T investment strategy
- NRAC long-range S&T review should be a continuing responsibility

In addition to the specific recommendations to counter technological threats and to enhance mission execution ability, six overarching issues are of concern to the Panel:

1. Formal mechanism for assessing U.S. vulnerabilities: The Panel believes that a formal mechanism should be developed to assess the vulnerability of U.S. Navy platforms, systems, and architectures. It is the Panel's opinion that the Navy needs to invest in a Red Team effort that looks not at specific threats, but rather examines U.S. Navy and Marine Corps platforms, systems, and architectures as an enemy would look at them, searching for tactical, logistic, and even strategic vulnerabilities. This Red Team effort should not be an intelligence community exercise, but an exercise with experienced line officers, engineers, and scientists who understand U.S. systems and capabilities and the availability of technologies to defeat them. The Panel proposes that this team should have heavy Information Warfare representation.*

This Red Team should focus on newly introduced systems and architectures as well as those still on the drawing boards. The primary questions the team should ask are "how do I defeat this?" "what are the vulnerabilities of the system?" and "where are the single points of failure?" The Panel believes that the FORCENet architecture should be among the first such issues to be subjected to a thorough analysis.

* The Panel is aware of the Office of Naval Intelligence Deep Red (N25) effort as well as related efforts at Dahlgren

2. Fundamental understanding of COTS: As noted above, the extensive use of COTS hardware and, in particular, software, introduces vulnerabilities because of the lack of complete and accurate documentation, inadequate testing, etc. In essence, the Navy must undertake an effort to determine the “DNA” of critical COTS components in critical combat systems and must make such determinations for future COTS systems before they are incorporated into critical systems. In this regard, the S&T community must help the Navy develop (1) business models, (2) technology drivers, (3) standards, and (4) an understanding of internal structure, functionality, and vulnerabilities of COTS.

While such efforts may be time consuming and will have a cost, the failure to do so could have critical consequences for the Navy.

3. Long-term program to develop an S&T workforce: The aging of the U.S. Navy laboratory workforce, the decline of U.S.-citizen graduate students in technology fields, and the difficulty in attracting recent graduates into government service indicate a potential crisis for the U.S. Navy’s laboratory system and S&T establishment. Additionally, the Panel finds a shortfall in a personnel management mechanism to develop naval officers with technological degrees and allow them to serve a successful shore “career” in S&T areas. If a long-term program to develop the Navy’s S&T workforce--including naval officers--is not put in place, the Panel fears that the Navy will not only lose its ability to field state-of-the-art technology, but will also seriously degrade its ability to understand world-wide technological developments well enough to prevent significant technological surprise.*

This area will require DoD leadership as well as a commitment by the Navy’s senior civilian and uniformed officials.

4. Improved coordination of R&D programs: The Panel believes that R&D efforts within the Navy are unduly fragmented, with one laboratory or development activity often being unaware of what another is doing. A similar situation exists with respect to other-service research efforts and those of some key allies (e.g., Britain and Israel). This situation leads to inefficient use of scarce resources. The Navy requires a mechanism to oversee and coordinate all internal Navy R&D activities, to include compartmented, special access programs, and those of non-Navy R&D activities.

5. Requirements-linked, long-range planning process for S&T investment strategy: The Panel was greatly surprised by the overall lack of long-term planning activities within the Navy.

Without a long-term strategic planning process it will be most difficult to develop an S&T investment strategy. While long-term strategic planning is outside the scope of this study, the Panel believes that a long-range S&T investment planning process is required.

* See, for example, Naval Research Advisory Committee report “Science & Technology Community in Crisis” (2002)

Such a planning process must be developed if the Navy is to have an effective shipbuilding plan, industrial base plan, threat analysis capability, and especially an effective S&T investment plan.

6. NRAC long-range S&T review should be a continuing responsibility: The Panel believes that the examination of S&T requirements to counter future threats should be an ongoing process. In this regard the Panel believes that such NRAC Panels should be continued and that they attempt to further develop and prioritize the findings and recommendations of this study.*

*The demise of Navy long-range planning is addressed in the Naval Research Advisory Committee report by David A. Rosenberg, "Historical Perspectives in Long-Range Planning in the Navy" (1980). Dr. Rosenberg is a senior professor at the U.S. Naval War College and chairman of the Secretary of the Navy's advisory committee on history.

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Recommendation 1

- Develop Long-Term S&T Planning Process

The ASN(RDA) should direct that his staff, the Chief of Naval Research, specific OPNAV codes, Marine Corps agencies, and appropriate Systems Commands and fleet organizations develop a long-term S&T planning process to help guide the future of Navy-Marine Corps S&T investment. Such a process should address (1) probable missions, (2) related systems capabilities, (3) related platform type requirements, and (4) related S&T requirements for required capabilities.

Further, it is proposed that the study sponsor, N6/7, recommend that this ongoing effort be made responsible to the Department of the Navy's S&T Corporate Board.*

Develop long-term S&T planning process: By definition, S&T are long-lead components of the development of advanced military weapons, sensors, platforms, and related systems. At the same time, an effective long-term S&T investment program cannot be developed without an understanding of probable future Navy-Marine Corps missions and force composition.

The Navy lacks a long-term, on-going planning process to develop a comprehensive view of naval requirements for the mid-range (i.e., 10 to 20 years). Some existing Navy activities that in the past have addressed long-term issues are now concentrating on counter-terrorism efforts. Although a long-range (30-year) shipbuilding plan does exist (having been produced in response to a congressional requirement), there is no associated or integrated planning process that addresses related manpower, base structure, and, especially, S&T requirements to support such long-term objectives.**

* Note: The S&T Corporate Board consists of the Vice Chief of Naval Operations, the Assistant Commandant of the Marine Corps, and Assistant Secretary of the Navy (RDA), with the Chief of Naval Research serving as Board Secretary.

** The recent efforts of the Naval Science Board of the National Academies in the field of naval aviation have a positive effect in this regard; see "Identification of Promising Naval Aviation Science and Technology Opportunities" (2005).

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Recommendation 2

- Develop Long-Term S&T Workforce Plan

The ASN(RDA) should determine the extent to which the NRAC report of 2002 has been implemented and remains valid with respect to the civilian S&T workforce. In collaboration with the Commander Naval Education and Training Command, the Chief of Naval Personnel, the appropriate Navy and Marine Corps systems commands, determine similar actions to be recommended for retaining uniformed personnel in the S&T workforce.

Develop long-term S&T workforce plan: The Navy lacks a long-term plan for the acquisition, management, and retention of a competent scientific and technical workforce--both civilian and military. Based upon statements to the S&T Panel by Navy experts, the technical education of the uniformed workforce has declined. This should be of particular concern to the Navy because of the increasing technical demands in all areas of naval activities.

NRAC previously addressed the civilian aspect of this problem in the report “Science & Technology Community in Crisis” (2002). Some recommendations of that report have been implemented by the DoD

An area of particular focus ought to be rectifying the unintended consequences of export control and security-clearance policies that tend to discourage foreign-born immigrants and second-generation citizens from entering government service or the larger national security technical work force.”

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Recommendation 3

- Accelerate Lower-Cost Platform Technologies

The ASN(RDA) should determine in conjunction with the Naval Sea Systems Command the means to initiate a comprehensive analysis to review new concepts for ship design and their implementation to date, and ensure that they are adopted to the maximum extent practical in the "next" Navy ship design. In particular, the extended service lives of contemporary warships demands that high priority be given to transition to these concepts prior to initiation of the next major surface ship or submarine design.

Accelerate lower-cost platform technologies: The increasing cost of U.S. Navy ships is undermining ship procurement while delaying the introduction of new technologies into the fleet. Several recent studies have recommended specific Life Cycle Technology Insertion (LCTI) and Technology Reform Actions as a means of reducing ship costs while providing enhanced capabilities. At the same time, the recent NRAC study "Science and Technology for Modular Systems" (March 2004) further highlights the need for a comprehensive approach to future Navy ship design and development.

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Recommendation 4

- Assess and Mitigate Long-Term COTS Vulnerabilities

The ASN(RDA) should form a joint task force representing the Office of Naval Research and the appropriate systems commands that would be empowered to develop a business model for assessing the potential vulnerabilities of COTS insertion into naval systems. Such an assessment should address technology drivers, standards, internal structure, functionality, and supportability, and include development of a program to enable mitigation of potential vulnerabilities.

Assess and mitigate long-term COTS vulnerabilities: The U.S. Navy is increasingly using COTS hardware and software. Economics and compressed development schedules often dictate the use of COTS in a variety of naval systems.

Yet COTS software seldom is fully documented and often has not been fully tested prior to commercial marketing. While the Navy does demand documentation and testing, neither is undertaken to the extent traditional with MILSPECdesigned-for-the-Navy software. The purchaser rarely knows the "internals" of what he is buying. While Trojan Horses, trap doors, and other vulnerabilities are of some concern, of more concern to the Navy should be the total lack of knowledge regarding how and why systems employing the COTS software may fail, issues of compatibility (with existing and future systems). Related to this is also the question of long-term support requirements for COTS software as the commercial market may deter the producer from continuing support for Navy-procured software and systems.

The Navy should develop a comprehensive effort to assess and to mitigate the long-term vulnerabilities of the integration of COTS into naval systems. This effort should, of course, address the relationships of COTS to Non-Developmental Items (NDIs) similarly integrated with naval systems.

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APPENDIX A

TERMS OF REFERENCE

Objective

Identify the science and technology in which the U.S. naval services should consider investing to counter predicted threats and to enhance the effectiveness of U.S. forces in the period 2015 to 2020 while undertaking Littoral Operations.

Background

The primary mission of the Department of the Navy is to develop and prepare Navy and Marine Corps forces to support the interests of the United States as directed by the President and the Secretary of Defense. This includes forces for the effective prosecution of war at sea and maintaining free access of the seas, including Littoral Operations; projecting military power ashore; providing air/missile defense in forward areas; and providing support to other U.S. military forces and coalition forces.

To accomplish this, the Department of the Navy must be cognizant of the capabilities, both current and predicted, that are available to other nations or terrorist organizations; that could threaten U.S. naval forces or their ability to execute assigned responsibilities; or interfere with naval intelligence, surveillance, and reconnaissance (ISR) and/or command, control, and communications activities. Based on this knowledge, the Department of Defense and the Navy can then better structure their investment in science and technology to ensure that operating forces can effectively counter such sensors and weapons to maintain a technological advantage on future battlefields.

Current U.S. Navy policy is to emphasize the preparation of forces for the Global War on Terrorism and Littoral Operations, generally defined as the projection of sea-based capabilities to the shore and inland, both in naval and in joint operations. This is in sharp contrast to the Cold War era in which U.S. naval forces were prepared primarily to counter Soviet naval and air forces in open ocean areas, and to support ground combat in Soviet peripheral areas and NATO regions. The increased importance of Littoral Operations imposes new sets of technological challenges on U.S. naval forces.

Accordingly, it is appropriate to establish a Naval Research Advisory Committee (NRAC) Panel to survey and categorize the requirements for naval science and technology needed to provide U.S. decision makers with information for developing future weapons, sensors, and related systems to effectively operate in littoral areas and support the Global War on Terrorism in the 2015--2020 time period. Further, the Panel shall focus on geographic areas that are (1) critical to U.S. political-military interests, and (2) potentially vulnerable to hostile interference of U.S. and Allied activities.

Specific Tasking

The NRAC Panel shall:

- (1) Survey and categorize the technologies for sensors, weapons, and related capabilities that will be available to potentially hostile forces in the period 2015—2020 and could interfere with U.S. naval operations.
- (2) Identify and qualify the feasibility of technological capabilities anticipated to be available to both the United States and anticipated adversaries in 2015—2020.
- (3) Contrast anticipated U.S. capabilities against probable adversarial forces to identify any capability gaps.
- (4) Identify planned U.S. science and technology investments that address capability shortfalls.
- (5) Identify capability gaps that are not being adequately addressed by current U.S. Navy (or other Defense Department/government agency) science and technology efforts.
- (6) On the basis of the above, provide recommendations for future naval science and technology investments.

APPENDIX B

Briefings and Discussions

Individuals

Dr. George H. Atkinson, S&T Advisor to the Secretary of State

Dr. Alan Berman, former Technical Director, NRL

Ambassador Linton Brooks, Under Secretary of Energy

Dr. Christopher Bowie, Deputy Director, Air Force Long-Range Planning

Dr. Richard Carlin, Director, Mechanics & Energy Conversion division, Office of Naval Research

Tom Clancy, novelist

RADM Richard Cobbold, RN (Ret), Director, Royal United Services Institute

RADM Jay Cohen, USN, Director of Naval Research

VADM James Fitzgerald, USN (Ret)

LTGEN James N. Mattis, USMC, CG, Marine Corps Combat Development Command

RADM William C. Miller, USN(Ret), Academic Dean, U.S. Naval Academy

Dr. David A. Rosenberg, Director, Task Force History

CAPT Gordon Wilson, RN (Ret.), former Director, Defence Studies (Naval)

Industry

Dr. Eric Horvitz, senior staff, Microsoft

George Pickett, Northrop Grumman

Dr. Scott Truver, Vice President, CSSO/Anteon

U.S. Government

Assessment Branch/OPNAV N81

Commander, Fleet ASW Command

Commander, Naval Special Warfare Command

Commander, Naval Surface Forces

Deep Red /OPNAV N2

DARPA (UAVs/Mechanical Bugs)

Office of Naval Intelligence (threat briefs, submarine technology)

ONR (UAVs, HI-FLY, non-acoustic ASW)

ONR Global/London (advanced air-defense concepts)

SPAWAR Systems Center (San Diego)

Strategic Studies Group (Naval War College)

British Government

Director of Intelligence (Maritime Systems)

Director General (Research & Technology)

Defense Science and Technology Laboratory

- Advanced radars
- Surface combatants/warfare
- Seabasing
- Electronic warfare
- Target identification
- Biological detection
- Littoral warfare
- ASW

APPENDIX C

Abbreviations

AAW	Anti-Air Warfare
AIP	Air Independent Propulsion
ASCM	Anti-Ship Cruise Missile
ASN (RD&A)	Assistant Secretary of the Navy (Research, Development, and Acquisition)
ASW	Anti-Submarine Warfare
C2	Command and Control
CNR	Chief of Naval Research
CNO	Chief of Naval Operations
CONOPS	Concept of Operations
COTS	Commercial Off-The-Shelf
CVN	Aircraft carrier (nuclear propulsion)
DD	Destroyer
DoD	Department of Defense
DON	Department of the Navy
DDX	Next Generation Destroyer
EM	Electro-Magnetic
EMCON	Emission Control
E.U.	European Union
FORCENet	Navy "Transformational" information-management architecture
GPS	Global Positioning System
IED	Improvised Explosive Device
IW	Information Warfare
JIC	Joint Intelligence Center
LCTI	Life Cycle Technology Insertion
MANPADS	Man-Portable Air-Defense System
MILSPEC	Military Specification
NATO	North Atlantic Treaty Organization
NDI	Non-Developmental Item
NRL	Naval Research Laboratory
OPNAV	Office of the Chief of Naval Operations
OSIS	Ocean Surveillance Information System
R&D	Research and Development
SDV	Swimmer Delivery Vehicle
SLOC	Sea Lines of Communication
SNR	Signal-to-Noise Ratio
SSBN	Ballistic missile submarine (nuclear propulsion)
SSN	Attack submarine (nuclear propulsion)
S&T	Science and Technology

UAV	Unmanned Aerial Vehicle
U.K.	United Kingdom
USV	Unmanned Surface Vehicle
UUV	Unmanned Underwater Vehicle
VV&A	Verification, Validation and Assurance
WMD	Weapons of Mass Destruction